

## TENSION ANCHORAGE SYSTEM

The present invention relates to an anchorage system for fibre reinforced polymer components.

## BACKGROUND OF THE INVENTION

[0001] A pre-stressed, pre-tensioned, or post-tensioned, concrete structure has significantly greater load bearing properties compared to an un-reinforced concrete structure. Steel rods or tendons are used almost universally as the pre-stressing or post-tensioning members. The steel rods and associated anchoring components may become exposed to many corrosive elements, such as de-icing chemicals, salt or brackish water. If this occurs, the rods may corrode, thereby causing the surrounding concrete structure to fracture.

[0002] Fibre-reinforced polymer (FRP) rods have been used in place of conventional reinforcing rods. The advantages of using a FRP rod include its light weight relative to steel, resistance to corrosion and its high tensile strength, which in some cases may exceed that of steel. Fibre reinforced polymer rods, however, do not have correspondingly high transverse compressive strength. As a result, traditional clamping or anchor mechanisms used for steel rods crush the rod at its load bearing area, which may lead to premature failure of the FRP tendon at the anchorage point.

[0003] Many solutions to this problem have been proposed, but none have resolved this problem satisfactorily. For example, Shrive et al (US 6,082,063) proposes a wedge anchor in which the taper of the wedge is greater than the taper of its receiving bore.

1 This differential tapering results in a higher clamping force being applied away from  
2 the rod's loaded area. However, Shrive et al requires very precise pre-seating of the  
3 wedge. Thus, its effectiveness is largely dependant on the precision of the pre-seating.  
4 Further, the Shrive et al design is not a robust design and it is not tolerant of machining  
5 inaccuracies.

6 [0004] There remains a need for a robust and easy to use anchorage system that is  
7 able to exploit the high tensile strength and non-corroding properties of carbon fibre  
8 reinforced polymer rods.

9  
10 SUMMARY OF THE INVENTION

11 [0005] According to the present invention there is provided a wedge anchor  
12 comprising a barrel having a wedge receiving face opposite a rod receiving face, a  
13 passage extending therethrough between the wedge receiving face and the rod  
14 receiving face, the passage narrowing toward the rod receiving face and having an axial  
15 cross-sectional profile defining a convex arc; and, a plurality of wedges insertable into  
16 the passage, each of the wedges having a respective inner wedge face for defining a rod  
17 receiving passage for receiving a rod and an outer wedge face, opposite the inner  
18 wedge face, in axial cross-section having a profile complementary to the inner barrel  
19 face.

20 [0006] The convex arc may define a radius of curvature.

1. [0007] The wedge anchor may further comprise a sleeve, which is insertable into the  
2 rod receiving passage for receiving an end portion of the rod, that may be comprised of  
3 a malleable metal, such as copper, aluminium and alloys thereof.

4 [0008] The present invention also provides for a method of testing the tensile  
5 strength of a carbon reinforced polymer rod comprising the steps of securing a wedge  
6 anchor according to an embodiment of the present invention to a rod end portion;  
7 applying a tensile force to the wedge anchor sufficient to break the rod; and, measuring  
8 the applied force.

#### 10 BRIEF DESCRIPTION OF THE DRAWINGS

11 [0009] These and other features of the preferred embodiments of the invention will  
12 become more apparent in the following detailed description in which reference is made  
13 to the appended drawings wherein:

14 [0010] Figure 1 is a schematic cross-sectional view of a wedge anchor according to  
15 an embodiment of the present invention;

16 [0011] Figure 2 is a schematic cross-sectional view of a wedge anchor according to  
17 an alternative embodiment of the present invention;

18 [0012] Figure 3 is a schematic cross-sectional view of a wedge anchor according to a  
19 further alternative embodiment of the present invention;

20 [0013] Figure 4(a) is a plan view of a wedge of a wedge anchor according to an  
21 embodiment of the present invention;

1    **[0014]**     Figure 4(b) is a cross sectional view of a wedge of a wedge anchor according  
2    to an embodiment of the present invention;

3    **[0015]**     Figure 5 is a cross-sectional view of a wedge and barrel portion of a wedge  
4    anchor according to an embodiment of the present invention illustrating the relative  
5    contact force exerted along the length of the wedge;

6    **[0016]**     Figure 6(a) is a schematic cross-sectional view of the rod-sleeve-wedge  
7    interface of a pre-seated wedge anchor according to an embodiment of the present  
8    invention;

9    **[0017]**     Figure 6(b) is a schematic cross-section view of the rod-sleeve-wedge  
10   interface of a secured wedge anchor according to an embodiment of the present  
11   invention;

12   **[0018]**     Figure 7(a) is a schematic cross-sectional view of the rod-layer-wedge  
13   interface of a pre-seated wedge anchor according to an embodiment of the present  
14   invention;

15   **[0019]**     Figure 7(b) is a schematic cross-section view of the rod-layer-wedge interface  
16   of a secured wedge anchor according to an embodiment of the present invention;

17   **[0020]**     Figure 8(a) is a cross-sectional view of a cast concrete structural member;

18   **[0021]**     Figure 8(b) is a cross-sectional view of the cast concrete structural member of  
19   Figure 8(a) illustrating a wedge anchor according an embodiment of the present  
20   invention secured to a fibre reinforced polymer rod;

1, [0022] Figure 8(c) is a cross-sectional view of the cast concrete structural member of  
2 Figure 8(b) illustrating wedge anchors secured to both ends of the fibre reinforced  
3 polymer rod; and,

4 [0023] Figure 9 is a schematic representation of a system for testing the tensile  
5 strength of a fibre reinforced polymer rod employing a wedge anchor according to an  
6 embodiment of the present invention.

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## 8 DESCRIPTION OF THE PREFERRED EMBODIMENTS

9 [0024] Referring to Figures 1 to 4(a) and (b), a wedge anchor 10 according to an  
10 embodiment of the present invention is illustrated. The wedge anchor 10 is comprised  
11 of a barrel 11 that has a wedge receiving face 13, which is opposite a rod receiving face  
12 15. A passage 17 extends through the barrel 11 between the wedge receiving face 13  
13 and the rod receiving face 15 and narrows toward the rod receiving face 15. In an axial  
14 cross-sectional profile, the passage 17 defines a convex arc 19. In a preferred  
15 embodiment of the present invention, the axial cross-sectional profile of the convex arc  
16 is defined by a radius of curvature 31 described as subtended angle less than  $0.5\pi$   
17 radians. The wedge anchor 10 also includes a plurality of wedges 21, which are  
18 insertable into the passage 17. Each of the wedges 21 has a respective inner wedge face  
19 23 for defining a rod receiving passage 25 for receiving a rod 27 and an outer wedge  
20 face 29, which is opposite the inner wedge face 23. The outer wedge face 29, in axial  
21 cross-section, has a profile complementary to the convex arc 19.

1. [0025] The wedge anchor 10 may include as few as two wedges 21, but generally  
2 will employ between 4 and 6 wedges 21. In a preferred embodiment, the wedge anchor  
3 10 is comprised of 4 wedges 21 of equal size.

4 [0026] The wedges 21 have a length 39 selected to ensure that they do not extend  
5 beyond the rod receiving face 15 of the barrel 11 when the wedge anchor 10 is in its  
6 assembled and secured configuration. In a preferred embodiment, the respective outer  
7 wedge faces 29 of wedges 21 have a length 39 less than  $0.5\pi$  radians. In an alternate  
8 embodiment, the length of the wedges 21 may extend beyond the rod receiving face of  
9 the barrel, provided a cast concrete structural member having a rod receiving entrance  
10 is configured to accommodate the extending wedges 21 without hindering the  
11 performance of the wedge anchor 10.

12 [0027] The barrel 11 and wedges 21 may be comprised of a hard material, such as a  
13 hard metal. In a preferred embodiment, the hard metal is stainless steel. However, any  
14 hard material known to those skilled in the art may be employed, such as titanium,  
15 copper alloys or ceramic materials. In an alternate embodiment, the barrel 11 and  
16 wedges 21 may be comprised of a hard plastic as is known to those skilled in the art.

17 [0028] Referring to Figure 5, a cross-sectional view of a portion of the wedge anchor  
18 10 in its assembled configuration and an accompanying force curve are illustrated. An  
19 inward radial or compressive contact force (F) is exerted along the length 39 of the  
20 wedge 21 when the wedges 21 are secured in the passage 17. The force curve illustrates  
21 the relative inward radial or compressive contact force (F) that is exerted along the  
22 length of the wedge 21. Line F illustrates that the compressive force F varies non-  
23 linearly over the length of the wedge anchor 10 as a function of the tangent along a  
24 surface point of the convex arc 19 and approaches a maximum toward the wedge



1. receiving face 15 of the barrel and a minimum toward the rod receiving face 13 of the  
2 barrel 11.

3 [0029] Referring to Figure 2, a preferred embodiment of the wedge anchor 10 is  
4 illustrated, which further includes a sleeve 33, which is insertable into the rod receiving  
5 passage 25. The sleeve 33 defines a sleeve passage 70 having an inner sleeve diameter  
6 71 that is configured to receive an end portion 37 of the rod 27. The sleeve 33 may be  
7 comprised of a malleable metal. In a preferred embodiment, the malleable metal is  
8 cooper or a cooper alloy (e.g. brass or bronze). The sleeve may also be comprised of  
9 aluminium, alloys of aluminium, and any other malleable metal known to those skilled  
10 in the art.

11 [0030] In an alternate embodiment, the sleeve 33 is comprised of a deformable  
12 material having sufficient shear strength to prevent shear stress failure of the sleeve 33  
13 and ensure that the rod 27 is held in place. For example, the sleeve may be comprised  
14 of a hard plastic as is known to those skilled in the art.

15 [0031] The sleeve 33 further includes a sleeve inner surface 75, which comes into  
16 contact with the rod 27. The sleeve inner surface 75 may be treated with a surface  
17 roughening agent (mechanical or chemical), which roughens the sleeve inner surface 75  
18 and thereby enhances the sleeve's 33 ability to hold the rod 27 in place. In a preferred  
19 embodiment, the inner surface 75 may be roughened by sandblasting. Any other  
20 roughening means known to those skilled in the art may be employed.

21 [0032] Referring to Figure 6(a), a wedge anchor 10 and its associated rod 27 are  
22 illustrated in their assembled configuration. The interface between rod 27, sleeve 33  
23 and wedge 21 is generally indicated by reference letter A. A magnified view of area A

1 illustrates that rod 27 has an outside surface 41 with surface gaps or irregularities 43.  
2 The inner wedge face 23 also has inner wedge face gaps or irregularities 45.

3 [0033] Referring to Figure 6(b), a wedge anchor 10 and its associated rod 27 are  
4 illustrated in a secured configuration. The interface between rod 27, sleeve 33 and  
5 wedge 21 is generally indicated by reference letter B. A magnified view of area B  
6 illustrates that when the wedges 21 are secured, a radial inward compressive force is  
7 applied to the rod 27 via sleeve 33. In effect, the sleeve 33 is squeezed between the rod  
8 surface 41 and the inner wedge face 23. This compressive force combined with the gaps  
9 and irregularities 43 and 45 causes deformation of the sleeve 33 that corresponds  
10 generally to the surface texture of the irregularities 43 and 45, effectively filling any  
11 surface gaps or irregularities 43 and 45. Accordingly, the sleeve 33 is selected to be of a  
12 thickness to ensure that sufficient sleeve 33 material exists to fill the gaps 43 and 45. In  
13 a preferred embodiment, the sleeve thickness is between 0.5 and 0.7 mm (or between  
14 1/15 and 1/20 of the inner diameter 71 of the sleeve 33).

15 [0034] Referring to Figure 3, an alternate embodiment of a wedge anchor 10  
16 according to the present invention is illustrated, which does not include the sleeve 33.  
17 In this embodiment, a layer 35, of the inner wedge face 23 is comprised of a malleable  
18 metal. The rod receiving passage 25 has a passage diameter 73. In a preferred  
19 embodiment, the malleable metal is copper or a copper alloy (e.g., brass or bronze). The  
20 sleeve may also be comprised of aluminium, alloys of aluminium, and any other  
21 malleable metal known to those skilled in the art may also be employed.

22 [0035] Referring to Figure 7(a), a wedge anchor 10 and its associated rod 27 are  
23 illustrated in their assembled configuration. The interface between rod 27 and wedge



21 is generally indicated by reference letter A. A magnified view of area A illustrates that rod 27 has an outside surface 41 with surface gaps or irregularities 43.

[0036] Referring to Figure 7(b), a wedge anchor 10 and its associated rod 27 are illustrated in a secured configuration. The interface between rod 27 and layer 35 of the wedge 21 is generally indicated by reference letter B. A magnified view of area B illustrates that when the wedges 21 are secured, a radial inward compressive force is applied to the rod 27 via layer 35. In effect, the layer 35 is squeezed between the rod surface 41 and the body of the wedge 21. This compressive force combined with the gaps and irregularities 43 causes deformation of the layer 35 that corresponds generally to the surface texture of the irregularities 43, effectively filling any surface gaps or irregularities 43. Accordingly, the layer 35 is selected to be of a thickness to ensure that sufficient layer 35 material exists to fill the gaps 43. In a preferred embodiment, the layer 35 thickness is between 0.5 and 0.7 mm (or between 1/15 and 1/20 of the passage diameter 73).

[0037] Referring to Figure 8(a) – (c), a use of the wedge anchor 10 according to an embodiment of the present invention is illustrated. Figure 8(a) illustrates a cast concrete structural member 51 having respective rod receiving faces 53 at opposite ends of the member 51, with a cavity or passage 55 passing through it between faces 53.

[0038] Figure 8(b) illustrates a fibre reinforced polymer rod 27, such as a carbon reinforced polymer rod, inserted in passage 55 and passing through member 51. A wedge anchor 10 is secured to a first end 57 of the rod 27. Once secured, a tensile force is applied to an opposite end 59 of the rod 27. Once a desired tensile force is applied, a second wedge anchor 10 is secured to the opposite end 59 of the rod 27, thereby

1 maintaining the tension over the length of the rod 27 and resulting in a compressive  
2 force, as indicated by force arrows 61, being applied to the member 51 (Figure 8(c)).

3 [0039] Referring to Figure 9, a system 67 for testing the tensile strength of a fibre  
4 reinforced polymer rod 27 is illustrated. The system 67 comprises a wedge anchor 10,  
5 which is secured to a test base 69. The wedge anchor 10 is also secured to one end of  
6 the rod 27. At an opposite end of the rod 27, a second wedge anchor 10 is secured. The  
7 second wedge anchor 10 is in turn connected to a force measuring unit 63, such that as a  
8 tensile force, as indicated by arrow 65, is applied, it is measured by the measuring unit  
9 63. In order to test the tensile strength of a rod 27, the tensile force 65 applied to the  
10 system 67 is increased until the force 65 applied exceeds the tensile strength of the rod  
11 27 and the rod 27 breaks. As the force 65 is applied, the measuring unit 63 measures the  
12 applied tensile force 65 and as such measures the force 65 applied at the moment the  
13 rod 27 breaks.

14 [0040] Although the invention has been described with reference to certain specific  
15 embodiments, various modifications thereof will be apparent to those skilled in the art  
16 without departing from the spirit and scope of the invention as defined by the claims  
17 set out below.